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FLIGHT TESTS OF INTERNALLY BALANCED, SEALED AILERONS
ON THE CURTISS XP-60 AIRPLANE

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CLASSIFIED DOCUMENT

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CONFIDENTIAL BULLETIN

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SUMMARY

Results are presented of brief flight tests of the aileron characteristics of the XP-60 airplane with internally balanced, sealed ailerons, which were developed by the NACA for use, particularly, on low-drag-type wings.

The results show that light and effective aileron control was obtained without evidence of overbalance or undesirable shaking of the control system at any part of the deflection range within the level-flight speed range.

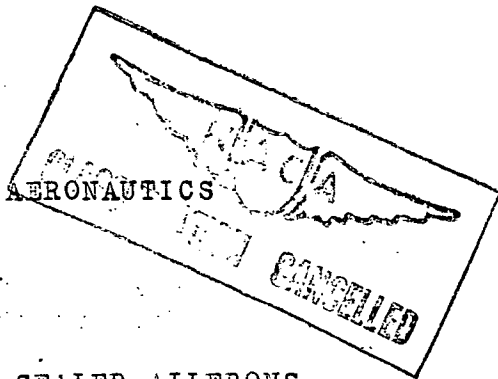
INTRODUCTION

At the request of the Army Air Forces, the NACA cooperated with the Curtiss-Wright Corporation in developing satisfactory lateral-control characteristics for the XP-60 airplane, which is equipped with a low-drag wing. In general, this work involved a series of wind-tunnel tests (unpublished) to develop an internally balanced, sealed type of aileron for use on this wing and brief flight tests of aileron characteristics with NACA recording instruments.

The flight tests, which are reported herein, were conducted in cooperation with the Curtiss-Wright Corporation at Buffalo.

DEVELOPMENT OF AILERONS

As originally constructed, the ailerons had an average chord of about 17.5 percent of the wing chord and extended from 48.5 to 90 percent of the wing semispan. The chord of the internal balance was about 35 percent of the aileron chord behind the hinge line.



These ailerons were considered heavy at high speeds and less effective than desirable by pilots of the Curtiss-Wright Corporation. Brief tests by the NACA, in which aileron effectiveness only was measured, substantiated the pilots' opinion but showed that the low effectiveness was caused by the failure of the aileron to deflect by the amount intended. The aileron effectiveness per degree aileron deflection was entirely normal.

Subsequent to these original flight tests and to various wind-tunnel investigations of aileron characteristics on low-drag-type wings, the ailerons of the XP-60 airplane were modified in accordance with recommendations of the Laboratory as follows:

1. The aileron chord was reduced from 17.5 percent to approximately 14 percent and the internal balance area was correspondingly increased to about 60 percent of the aileron chord.

2. The control-cable system was replaced by push-pull rods.

3. The ailerons were extended to the wing tip and a linked tab was installed for final adjustment of the hinge moments.

4. The internal seal was made continuous through the aileron hinges and around the ends of the balance area.

After preliminary flights with the modified ailerons, the linked tab was found unnecessary and was locked in neutral. With this arrangement, the aileron-operating forces were reported as being very light. NACA recording instruments were again used at this time to measure aileron effectiveness. The results of these measurements indicated the need for some further increase in effectiveness so that the aileron balance was made thinner to permit an increase in aileron-deflection range.

Following this final change, the aileron-operating forces were measured. These measurements were made at the same airspeeds for which the data on aileron effectiveness had been obtained in the previous tests.

This report presents the existing flight-test data for the final aileron installation. Because the experimental data for aileron effectiveness were obtained before

the final increase in deflection range, an extrapolation was required in order to arrive at values for the final installation. Experience indicates that, for the range of deflections involved, such a procedure is reliable.

FINAL WING-AILERON ARRANGEMENT OF XP-60 AIRPLANE

The following dimensions of the XP-60 airplane are of interest in connection with the aileron characteristics:

Wing span, feet	41.4
Wing taper ratio	3:1
Aileron chord, percent of wing chord	Approximately 14
Aileron location:	
Inboard end, percent $b/2$	48.5
Outboard end	Wing tip
Airfoil section:	
At root	NACA 66-2-118
At tip	NACA 66-2x-116
Aileron balance	Internally sealed type
(Balance chord approximately 60 percent of aileron chord with seal carried unbroken through hinges and around ends.)	

The relation between aileron angles and the position of the grip of the control stick is shown in figure 1. The plan form of the wing and aileron arrangement is shown in figure 2. A schematic section view of the wing-aileron arrangement showing general proportions of aileron chord, aileron balance chord, and wing chord is shown in figure 3.

APPARATUS AND TESTS

NACA recording instruments were used to record aileron position and the rolling velocity of the airplane. Airspeed, altitude, and free-air temperature were recorded by the pilot from the standard airplane indicating instruments. Aileron-control forces were recorded by the pilot from an NACA portable-type stick-force indicator.

The NACA test procedure was used to determine aileron effectiveness. Abrupt aileron rolls were made from laterally level flight at various airspeeds with the rudder held fixed by the pilot in its trim position. Aileron

effectiveness was measured for various aileron deflections at indicated airspeeds of 166, 214, and 268 miles per hour. These speeds correspond to airplane lift coefficients of approximately 0.48, 0.29, and 0.18, respectively. No tests were made at lower speeds or with flaps and landing gear down.

Aileron-operating forces were determined similarly by recording the force required at the grip of the control stick for various aileron deflections at these airspeeds.

RESULTS AND DISCUSSION

The results obtained are presented in figures 4 and 5. Figure 4 shows the variation of the aileron effectiveness factor $pb/2V$ with total aileron deflection, the total aileron deflection being the sum of up-and-down aileron deflections used in the roll. These measurements were made with the ailerons having a restricted deflection range; hence, test points do not exist for the full-deflection range later incorporated and for which the control forces were measured. Previous experience indicates that, for the range of deflections involved, the linear extrapolation used to obtain values for full deflection is entirely reliable. It will be noted that, with full deflection, the values of $pb/2V$ obtained would exceed the limit of 0.07 radian suggested as a minimum allowable limit for satisfactory lateral control (reference 1). At the highest speed tested, 268 miles per hour, the values of $pb/2V$ obtained for a given aileron deflection were about 20 percent greater than at lower speeds, although occasional points in rolls to the right at lower speeds also fell on the steeper curve.

Figure 5 shows the variation of stick force with aileron deflection at various indicated airspeeds. The stick force required per degree aileron deflection increased rapidly as full deflection was approached, although in every case it varied smoothly with aileron deflection and the forces required were satisfactorily small.

Figure 6 was constructed from the data of figures 4 and 5 to show the variation of rolling velocity with indicated airspeed for a 30-pound stick force, 30 pounds being a reasonable upper limit for aileron-operating force for pursuit airplanes. Similar curves for the

Spitfire, Hurricane, and P-40 airplanes are shown for comparison. The ailerons of the XP-60 airplane show up well against those of the other airplanes. It may also be mentioned that the ailerons of the XP-60 exceed slightly the requirement that ailerons of pursuit airplanes should produce a helix angle $\phi_b/2V$ of at least 0.07 radian at 0.8 maximum level-flight speed with a stick force no greater than 30 pounds.

CONCLUDING REMARKS

Several other items may be mentioned regarding the internally balanced ailerons as applied to the XP-60 airplane. In addition to providing exceptionally light and effective lateral control at high speeds, the ailerons apparently give adequate effectiveness at low speeds and with flaps down. This statement is based on pilots' reports as, unfortunately, no quantitative data cover this point.

Another point of interest is the complete freedom from aileron vibration, shuddering, or overbalance throughout the speed range of the airplane or at full throw of the control stick.

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National Advisory Committee for Aeronautics,
Langley Field, Va.

REFERENCE

1. Gilruth, R. R., and Turner, W. N.: Lateral Control Required for Satisfactory Flying Qualities Based on Flight Tests of Numerous Airplanes. Rep. No. 715, NACA, 1941.

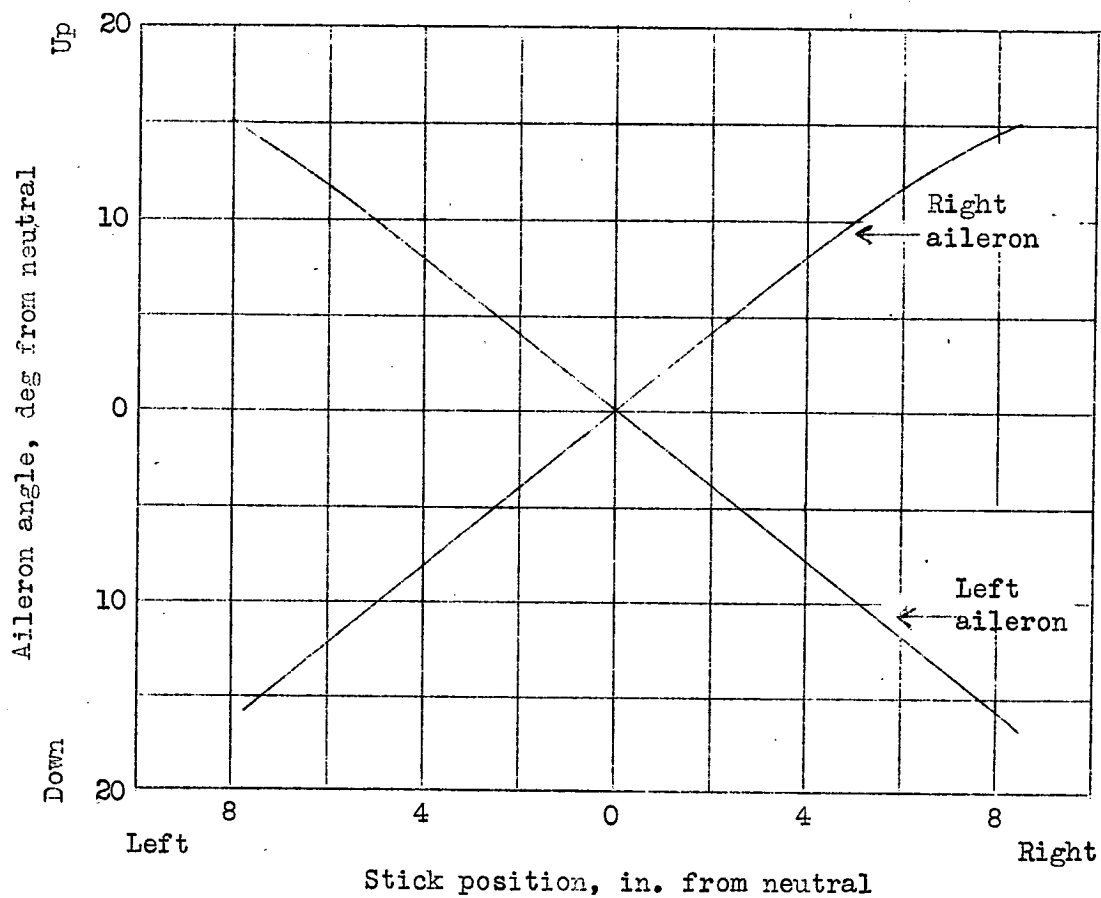


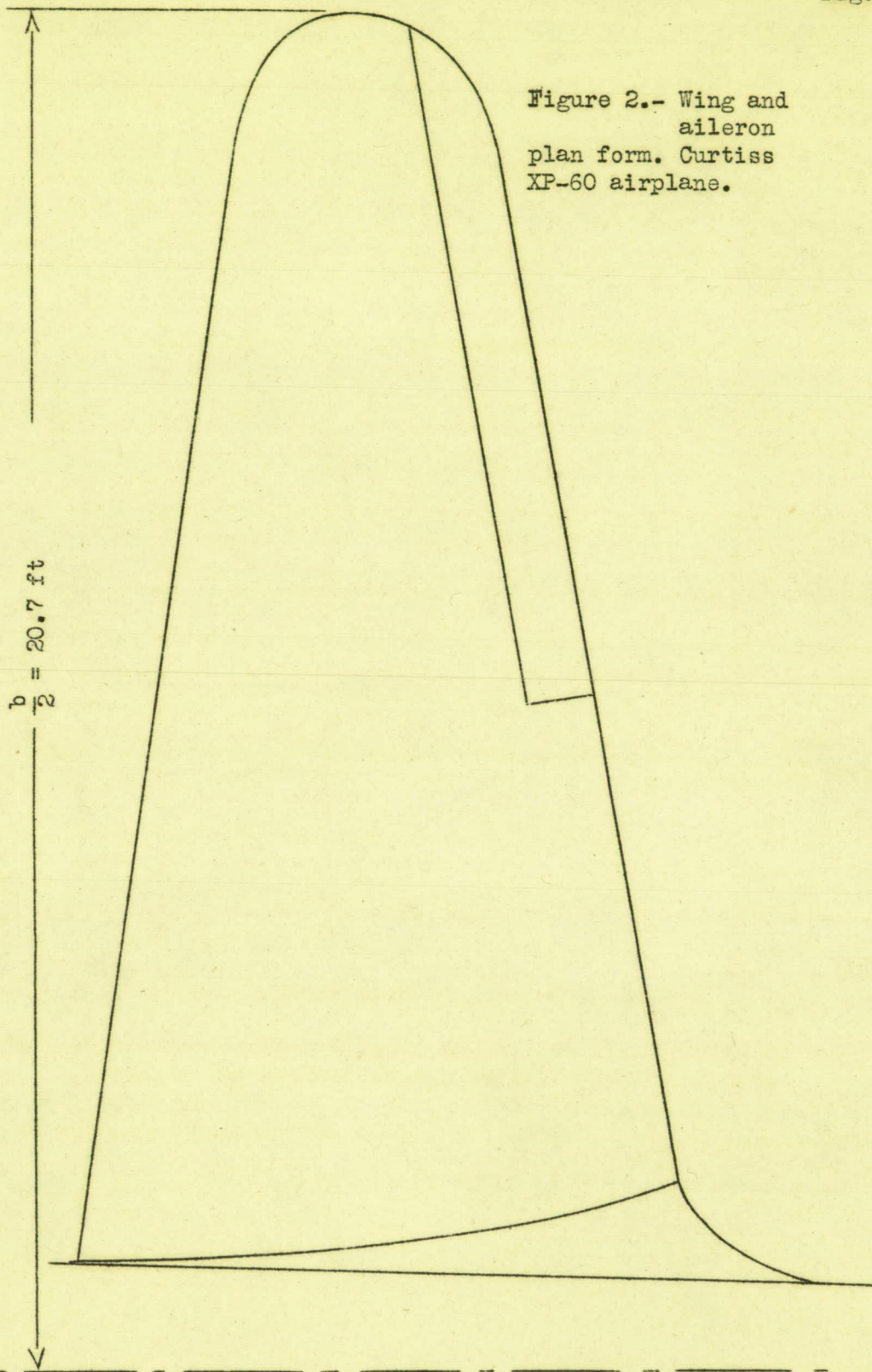
Figure 1.- Relation between aileron angles and the position of the grip of the control stick. Curtiss XP-60 airplane.

NACA

Fig. 2

Figure 2.- Wing and
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plan form. Curtiss
XP-60 airplane.

$\frac{b}{2} = 20.7 \text{ ft}$



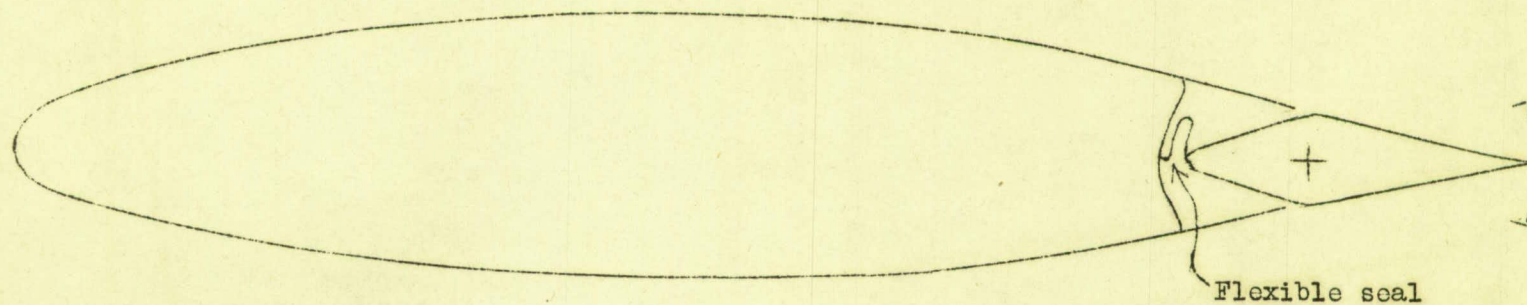


Figure 3.- Schematic view of internally sealed balanced aileron as applied to low-drag-type wing on Curtiss XP-60 airplane.

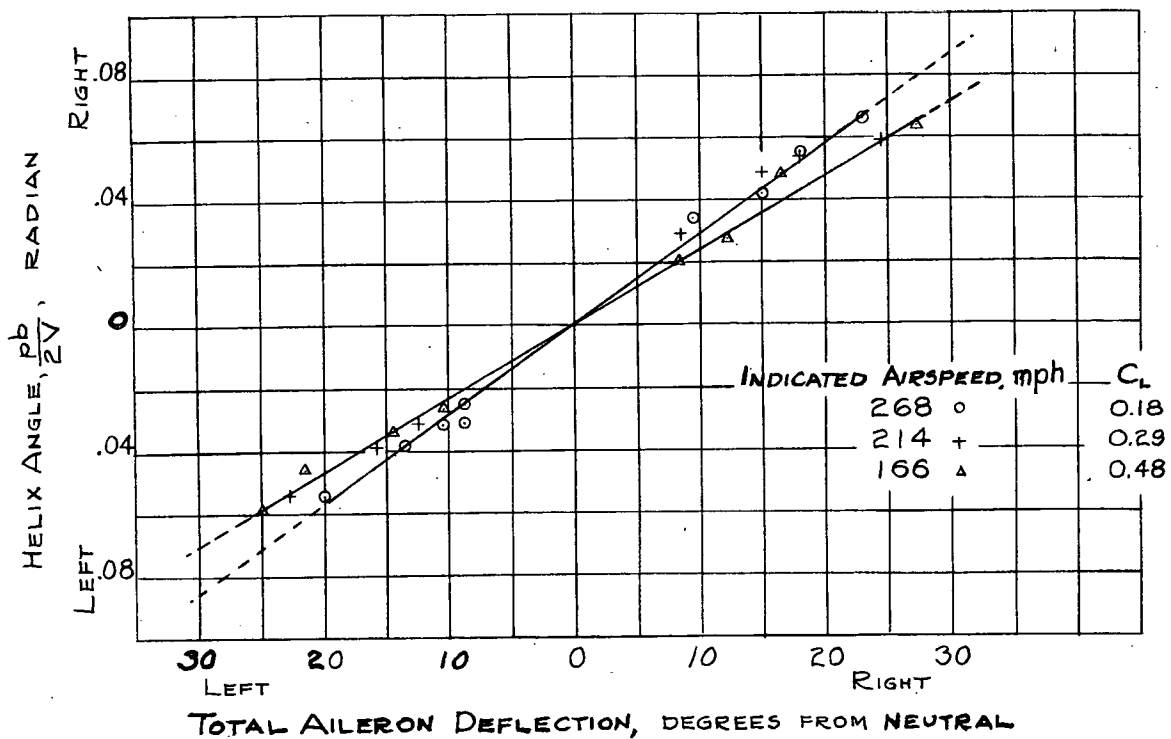


Figure 4.- Variation of aileron effectiveness factor $pb/2V$ with aileron deflection. Curtiss XP-60 airplane.

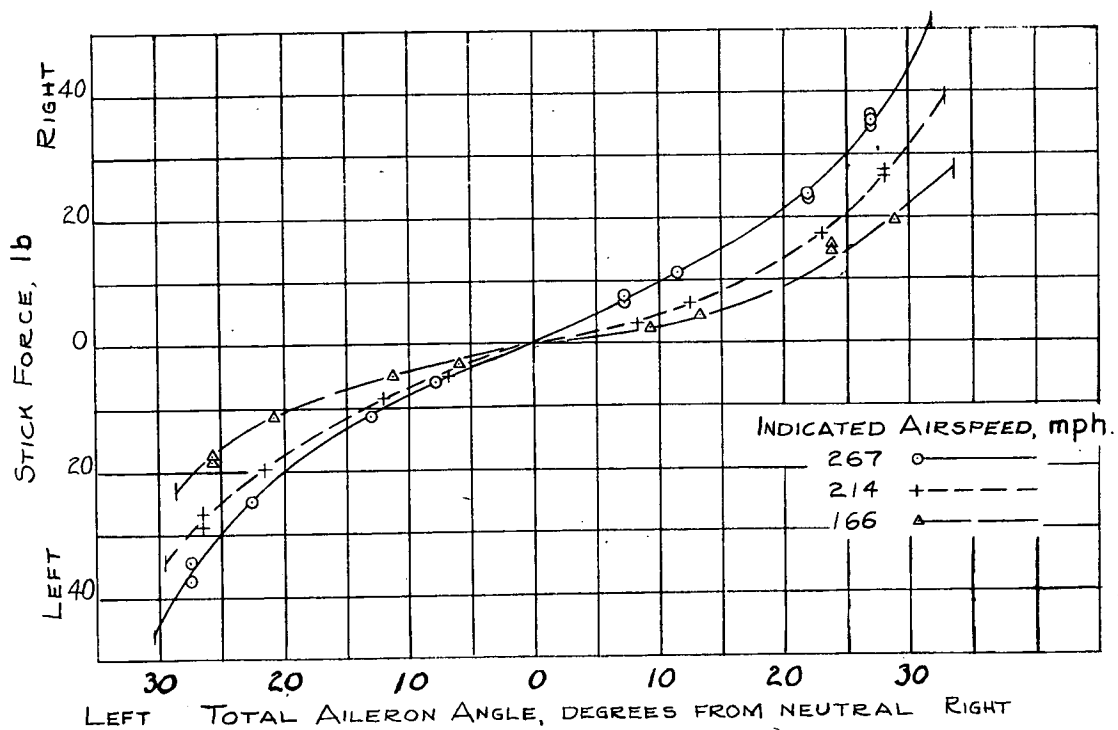


Figure 5.- Variation of aileron control force with aileron deflection. Curtiss XP-60 airplane.

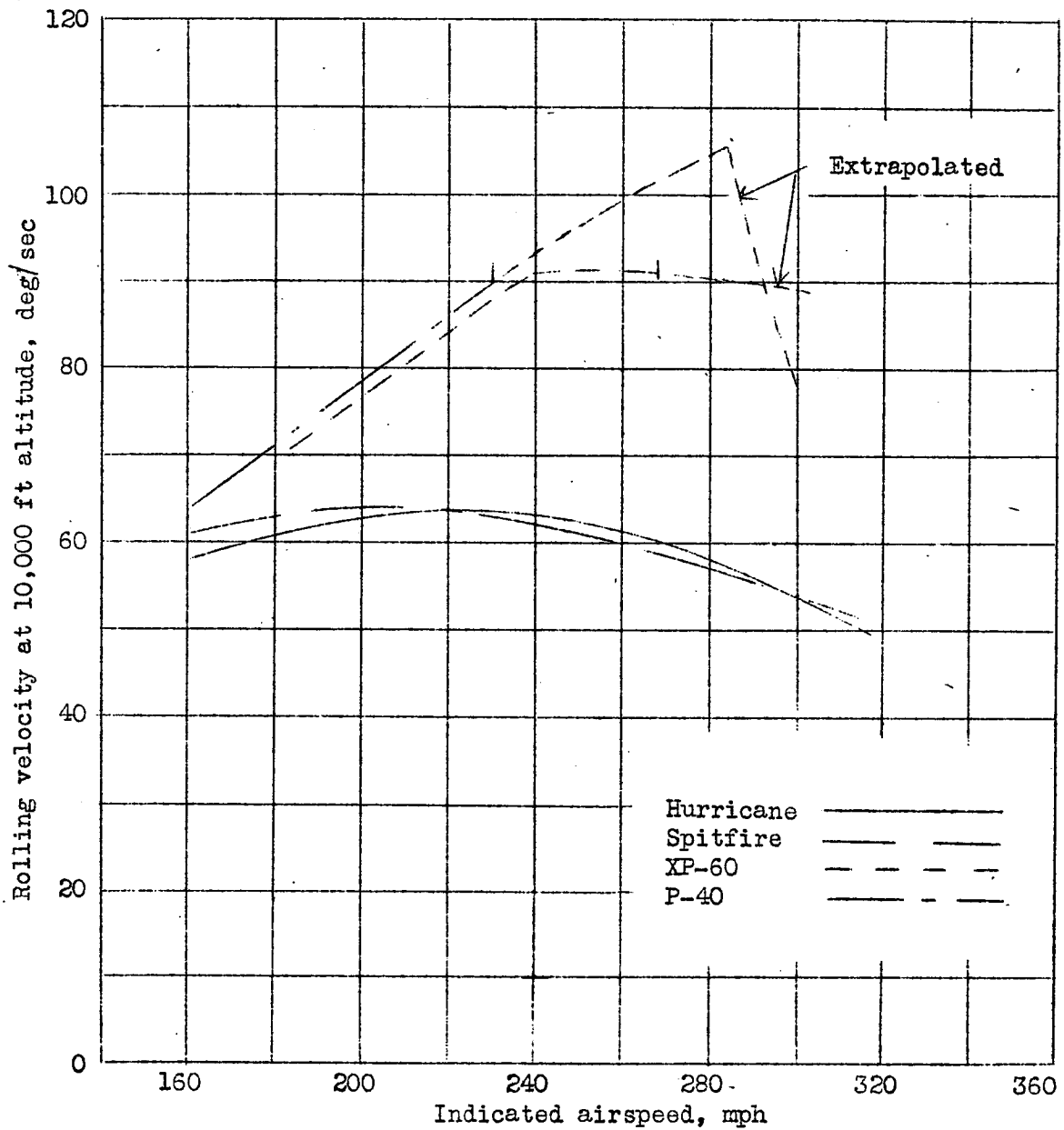


Figure 6.- Comparison of rolling velocities of XP-60 airplane with those of other pursuit airplanes for a 30-pound stick force at 10,000 feet altitude.